Fire Growth and Spread on Thermoplastic Objects

BFRL has three related projects:

- Nano-Additive Flame Retardants for Polyurethane Foams
- Fire Growth and Spread on Thermoplastic Objects
- Modeling Melt Flow Using Particle Methods

Goals:

- **A flammability test method useful in the NIST effort to develop less flammable polyurethane foams for residential applications (soft furnishings)**

- **A model of fire growth on generic configurations of thermoplastic materials also of use to the NIST effort**

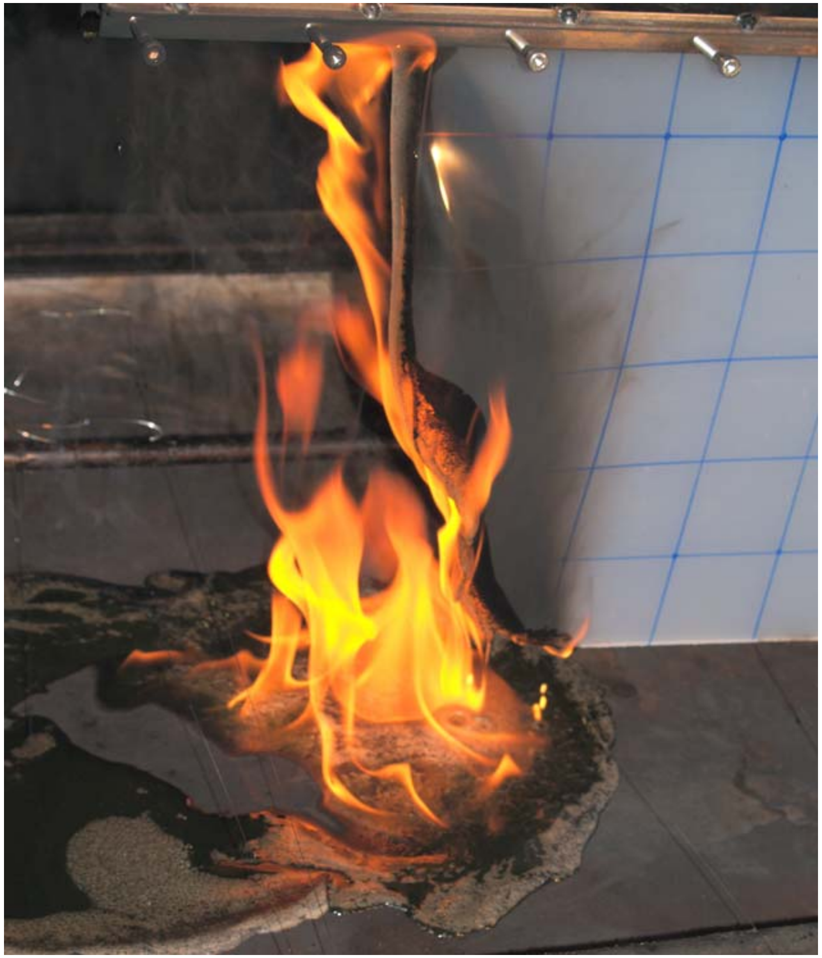
Approach:

Develop data in parallel on thermoplastics and on foams emphasizing the model first for thermoplastics and the test method first for foams.

- medium scale fire growth experiments on simple thermoplastics and on polyurethane foams of varied configuration and composition

- smaller-scale experiments to study isolated aspects of the behavior of the materials

Generic Fire Growth Configurations



Stepwise Modeling Approach

- Two-Dimensional (Radiant Heat Flux)
  - Melting
  - Melting & Gasifying
  - Melting & Gasifying with Flow onto Pool

ATTACH FLAME

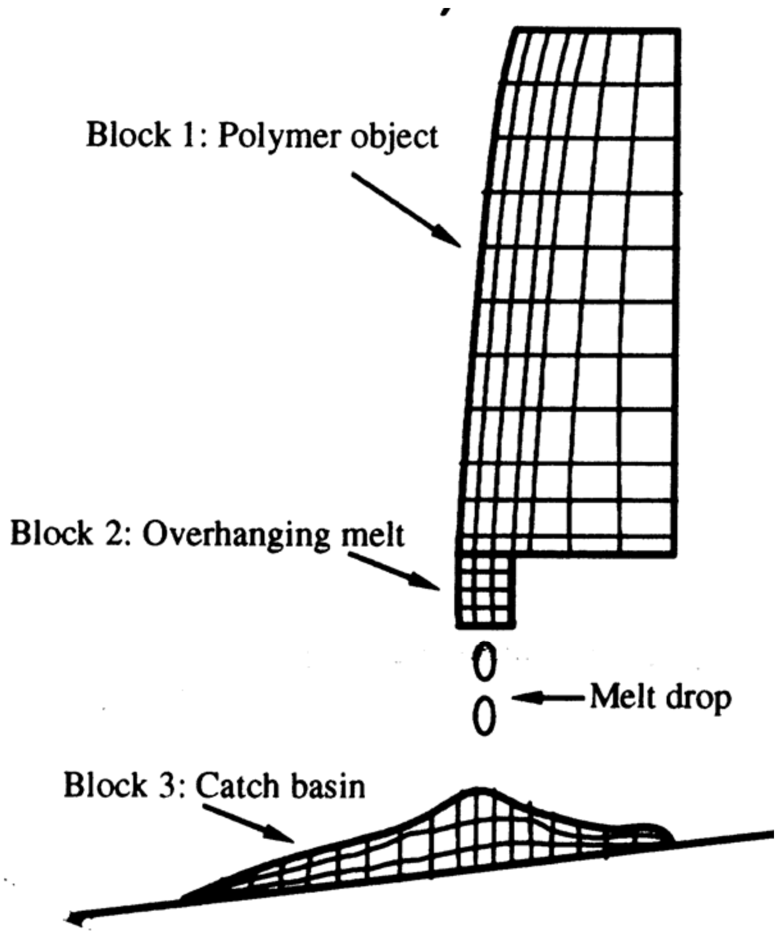
  - Melting, Gasifying, Burning
  - Melting, Gasifying, Burning with Pool Fire
- Three-Dimensional Fire Growth
  - Thermally-Thin Solid Thermoplastic
  - Vee Configuration Polyurethane Foam

Reaction Engineering International

- Commercial software codes gave very long solution times for the early stage problems

- REI was contracted to adapt their industrial furnace-modeling code to the NIST condensed phase problem

Reaction Engineering International



- Time-varying multi-block grid
- Finite volume discretization of Navier-Stokes eqns
- Free surface position from surface flow velocity
- Re-grid each time step

Reaction Engineering International

- Completed model results for 2-D melting & gasification of two polypropylenes of differing melt viscosity
- Comparisons with cone calorimeter-based experiments raise questions about model accuracy/input parameter accuracy
- Solution times in 10-20 hours range
- Now addressing melt flow on catch surface; solution times again comparable

Particle Finite Element Method

International Center for Numerical Methods in Engineering, Barcelona, Spain,

Basic PFEM algorithm:

1) **Particles with a given velocity, density, gravity, etc**

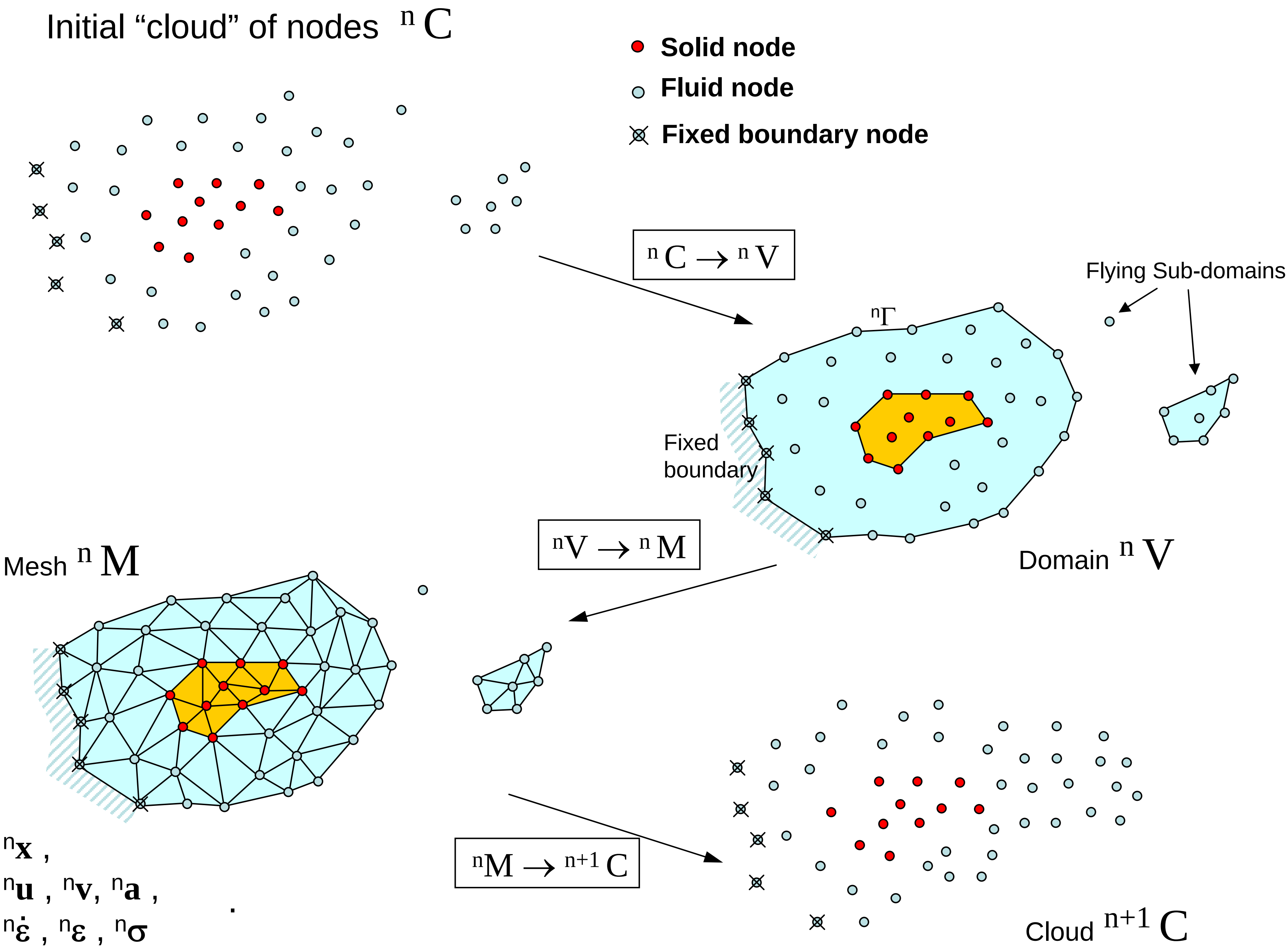
2) **Definition of a volume and a boundary.**

3) **Evaluation of the forces on the particles by solving the Navier-Stokes equations using the FEM.**

    This requires generating a mesh.

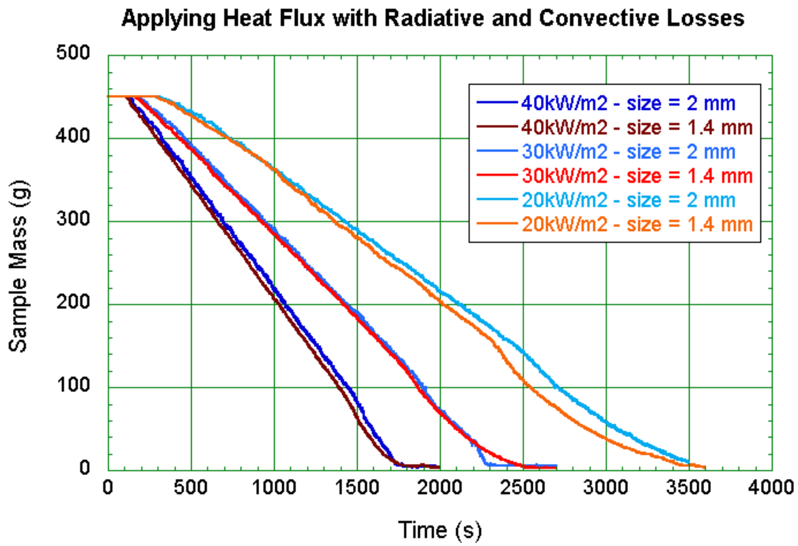
4) **Evaluation of the velocity and acceleration of each particle**

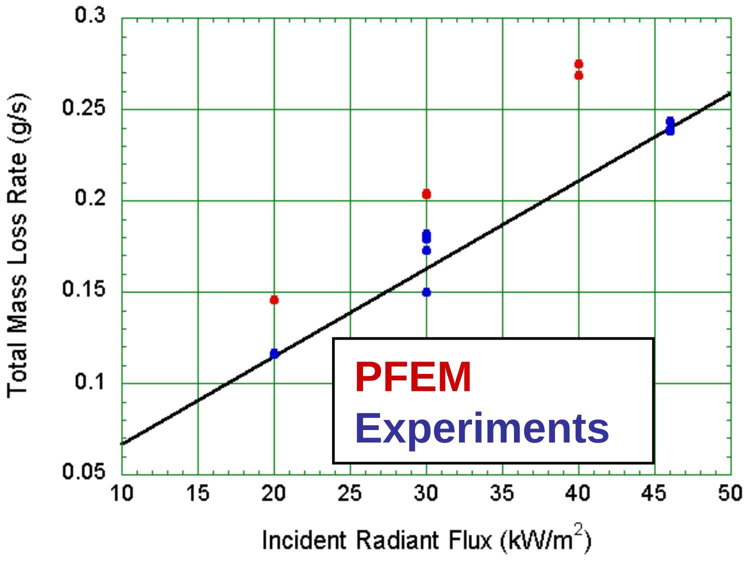
5) **Move the particles and go to 1)**

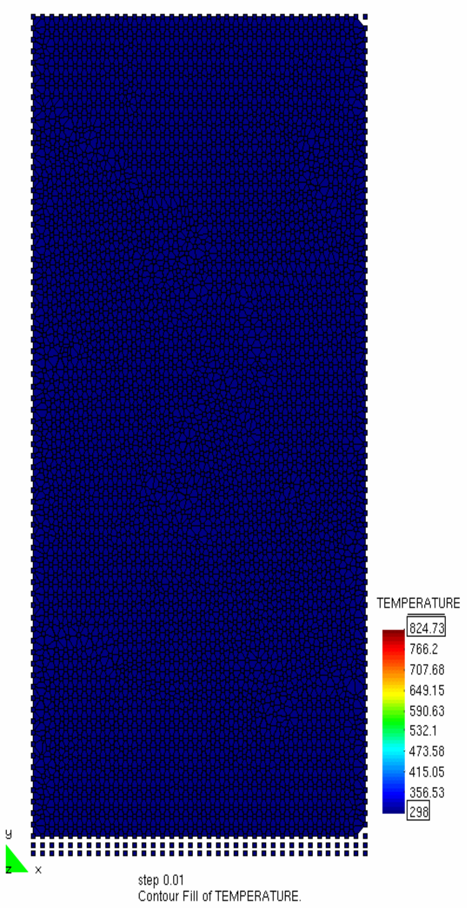


Initial "cloud" of nodes ^{n}C
Solid node
Fluid node
Fixed boundary node
$^{n}C \rightarrow {}^{n}V$
Flying Sub-domains
$^{n}\Gamma$
Fixed boundary
Domain ^{n}V
Mesh ^{n}M
$^{n}V \rightarrow {}^{n}M$
$^{n}\mathbf{x}$,
$^{n}\mathbf{u}$, $^{n}\mathbf{v}$, $^{n}\mathbf{a}$,
$^{n}\dot{\boldsymbol{\varepsilon}}$, $^{n}\boldsymbol{\varepsilon}$, $^{n}\boldsymbol{\sigma}$
$^{n}M \rightarrow {}^{n+1}C$
Cloud ^{n+1}C

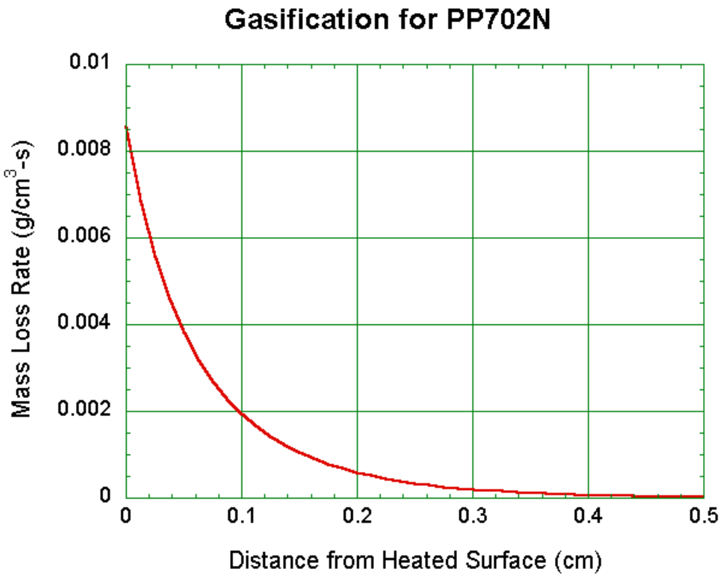
Steady Heat Flux
with Radiative and Convective Losses

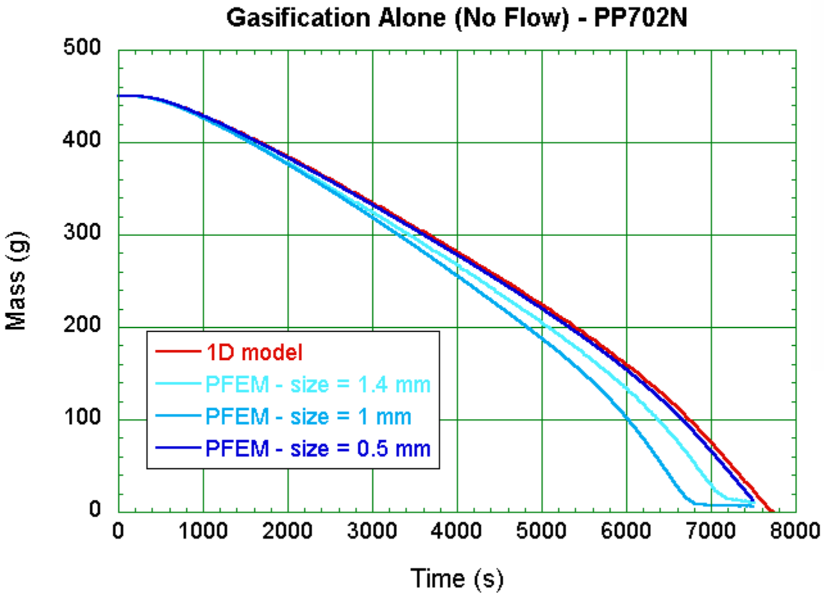


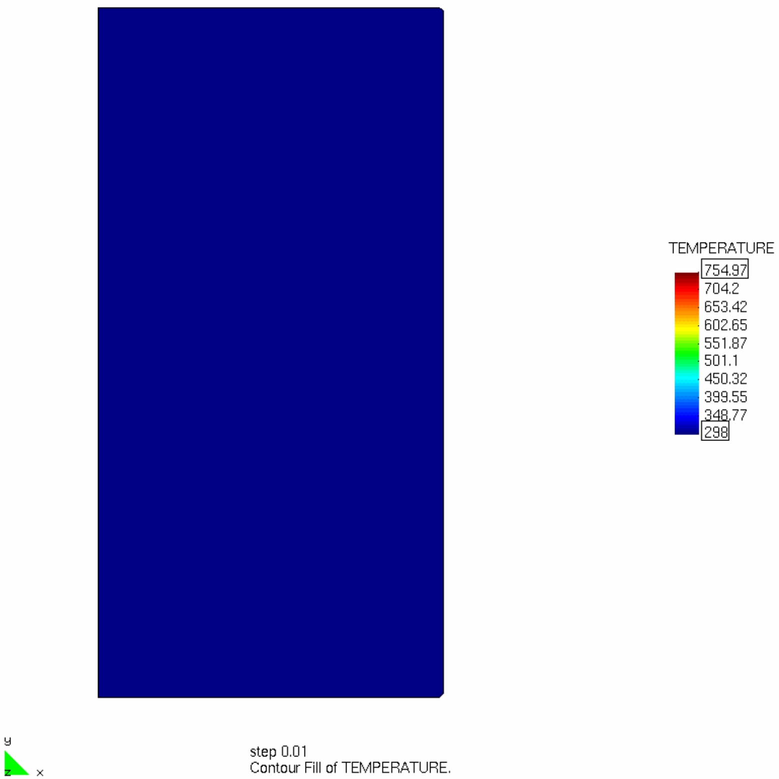


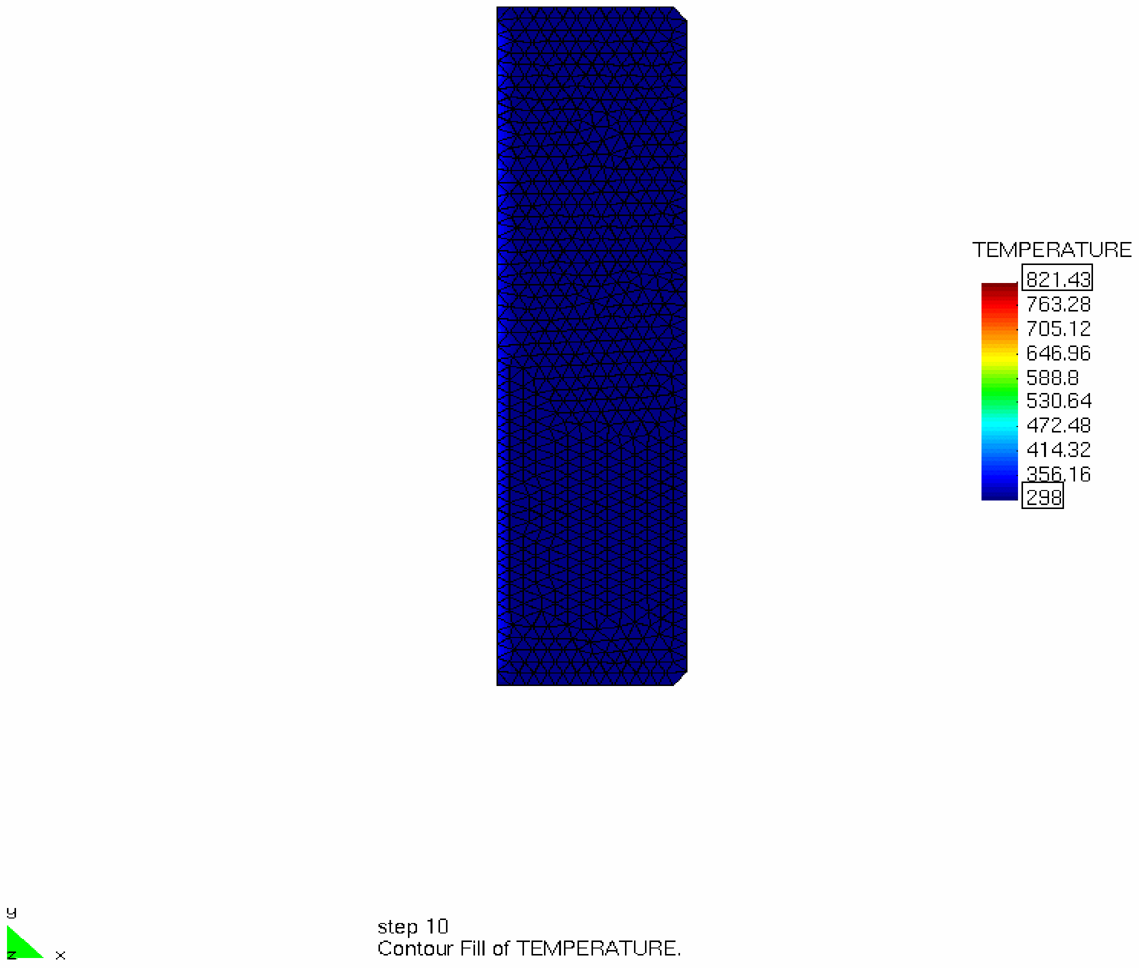


Gasification








TEMPERATURE
821.43
763.28
705.12
646.96
588.8
530.64
472.48
414.32
356.16
298
y
z
x
step 10
Contour Fill of TEMPERATURE.

Next Steps

- Experimental
  - Assessment of flammability test method at medium and full-scales
  - Description of polyurethane foam melt characteristics
- 2 model approaches
  - Choice of most promising model approach
  - 2-D and 3-D burning cases